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FASCIA SCIENCE AND CLINICAL APPLICATIONS: FASCIAL PATHOPHYSIOLOGY IMAGING

Case study: Could ultrasound and elastography visualized densified areas inside the deep fascia?

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Summary Many manual techniques describe palpable changes in the subcutaneous tissue. Many manual therapists have perceived palpable tissue stiffness and how it changes after treatment. No clear demonstration exists of the presence of specific alterations in the subcutaneous tissue and even less a visualization of their changes following manual therapy.

This case study visualizes by ultrasound and elastography an alteration of the deep fascia in a 40-year-old male with subacute pain in the calf area. Ultrasound and elastography permits visualization of gliding, echogenicity and elasticity of deep fascia and their changes, after manual therapy (Fascial Manipulation©).

This study suggests the possible use of the ultrasound and elastography to furnish a more objective picture of the "sensations" that are commonly reported by manual therapists, and which supports clinicians in the diagnosis of the myofascial pain.

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Introduction

Ever since Hippocrates, palpation has been used to detect differences in tissue stiffness. Many manual techniques describe the presence of various alterations in the subcutaneous tissue that are appreciable with alpation, and most manual therapists have perceived stiffness variation after treatment (Huguenin, 2004). Really, no clear demonstration of the presence of specific alterations in the subcutaneous tissue exists and even less a visualization of their changes with manual therapy. Palpation may be able to reveal the presence of a mass or hardening of tissue, however it cannot demonstrate the localization of the problem (is it in the muscle or into the fascia?).

For many years researchers looked for muscular alterations, but recently some authors suggest the possible role of the deep fascia (Stecco et al., 2008; Van der Wal, 2009; Benjamin, 2009). Conventionally, connective tissue has been seen as a container and a force transmitter. The current knowledge concerning fascia is mainly based on dissections and on the macroscopic, histological and cadaveric studies. Less is known about factors affecting the fascial system of living individuals. Studies (Stecco and Stecco, 2009; Van der Wal, 2009; Corey et al., 2011; Tesarz et al., 2011) have pointed out the role of proprioception, motor control and activation of the fascial system. Many questions still remain unanswered.

Recently, the development of ultrasound and elastography instruments furnishes the clinicians with a new method to detect and display the relative stiffness of tissue within the body, as well as stiffer nodules in the specific regions of tissue (Konofagou et al., 2003), opening a host of new opportunities and perspectives (Sikdar et al., 2009; Supriyanto et al., 2011). Ultrasound can assist in teaching the role of palpation of functional anatomy. This teaching method is known as sonopalpation (Heiskanen and Comerford, 2012).

Ultrasound devices enable detection of superficial and deep fascia and their independent or dysfunctional movements and structures; regularity, shadows, homogeneity, reflectivity and density. Also functional aspects such as gliding can be visualized (Gao et al., 1996, Bianchi and Martinoli, 2007). The ultrasound imaging method provides an accurate, reliable, non-invasive means of evaluating muscles size, shape and architecture, and the effects of different pathologies and interventions have been documented (Whittaker, 2007). It uses colors to mark different tissue permeability in different colors. The muscle layers appear darker with fewer shades of grey while the encapsulating fascia appears quite white.

Elastography also known as elasticity imaging, is an *in vivo* non-invasive assessment of mechanical strain changes in tissues. A compressive force is applied to the tissue surface to produce transverse tissue displacement. The amount is estimated by comparing the echo signal sets obtained before and after compression. Real-time freehand ultrasound elastography (RTE) is the simplest technique allowing direct viewing of the elastogram superimposed on the B-mode image. The main limitation in this method is subjectivity since the operator manually controls the transducer. Thus, the pressure, orientation and direction of the ultrasound transducer can change the resulting images (Drakonaki et al., 2009).

Both ultrasound and elastography provides an extra dimension that complements existing imaging technology of gray scale and color Doppler imaging by showing differences in tissues elasticity (Ophir et al., 1991; Konofagou et al., 2003). The major problem of ultrasound and elastography is that they furnish operator-dependent images, that are often not easy to interpret. To better understand ultrasound images, it is necessary to keep in mind the organization of the fascial apparatus. The anatomy of the human fascial system can be divided into different layers (Fig. 1).

Superficial fascia lies beneath the epidermis and corium (Stecco and Stecco, 2009) and adheres via ligamentous folds into the deep fascia. It is clearly visible by ultrasound as a white fibrous layer in the middle of the adipose subcutaneous tissue. Functionally, the superficial fascia may play a role in the integrity of the skin, in thermal regulation, metabolism and the protection of vessels and nerves and in participating in the perceptive system (Stecco et al., 2008). The superficial fascia is formed by interwoven collagen fibers, which are loosely packed together and mixed with abundant elastic fibers. Due to the undulated collagen and elastic fibers, the fascia stretches and then returns to its original resting state.

The deep fascia envelops the muscles and their aponeurosis up to where it is inserted into the bone (Schleip et al., 2012). The deep fascia and muscles work together like a transmission belt between two adjacent joints and also between synergic muscle groups. Different levels of innervation can be recognizable inside the fascia, according to their different roles in movement, coordination and perception (Benjamin, 2009; Schleip et al., 2012). The deep fascia of the trunk is very different from that of the limbs. In the limbs fascia is easily separable from the underlying muscles because under the deep fascia, the muscles are free to slide because of the epimysial fascia. In the trunk, the deep fascia cannot be separated from the muscle. So, only the deep fascia of the limbs (and the thoracolumbar fascia and rectus sheath) are clearly visible with ultrasound. In the limbs, the deep fascia has a composite structure forming 2–3 layers of parallel bundles of collagen fibers. Each layer is separated from the adjacent one by a thin layer of loose connective tissue; this system allows the layers to slide one on the other. Overuse, trauma, disuse and misuse can compromise capacity of the sliding system. Different orientation of collagen fibers creates a strong resistance to traction even when the muscle is exercised in different directions. This sublayer organization could be studied by ultrasound, but it is necessary to use a high definition probe (Stecco et al., 2008).

The aim of this case study is to visualize a densification inside the deep fascia and compare its status before and after a manual treatment.

Materials and method

This case study was conducted in Finland with the ultrasound machine GE Healthcare's LOGIQ P6 that is equipped with elastography. LOGIQ P6 provides the modalities of SR,

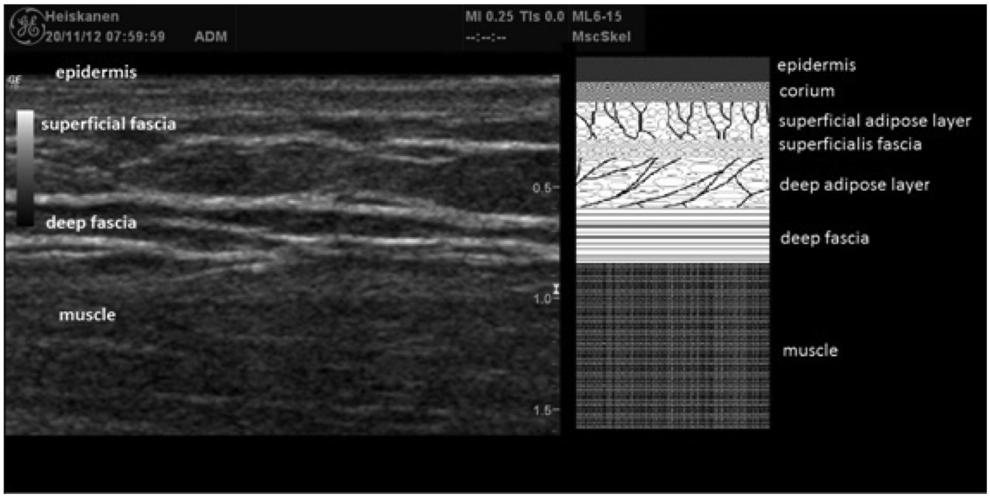

Figure 1 Comparison between the scheme of the subcutaneous tissue and fascial layers by Stecco (right side) and the subcutaneous tissue of the calf area as visualized by ultrasound (left side).

the ultrasound probe used in this study was a linear 6–15 MHz probe. The elastography measures the axial elasticity or compressibility. A colored code shows the elastic properties of the fascia so that compressible, elastic tissue is shown as red and non-elastic and stiffer fascia is blue. Yellow to green represents tissue elasticity in the mid-range of elasticity.

This is a case report where the subject was a 40-year-old male with an active physical background. He had no serious injuries or chronicity. The subject had subacute pain in the calf area referring towards the Achilles tendon and heel. He also felt general stiffness around the calf area.

In this case study, Fascial Manipulation © was used as a treatment technique. Fascial Manipulation© is a manual therapy developed by Luigi Stecco. It described a hundred specific areas, called centers of coordination, located into the fascia where vectorial forces of the fascia meet and muscular traction occurs (Stecco, 2004). The map of the centers of coordination guides the treatment with the idea of restoring the tensional balance. It is believed that if these specific areas are altered (densified), the entire myofascial unit contracts in an anomalous manner resulting in non-physiological movement of that segment, causing pain and stiffness. When the altered center of coordination is identified, a localized pressure/friction (knuckles, elbow etc.) for a few minutes using forces ranging from 30 to 70 N in that point (Fig. 2) could restore the normal gliding of the fascia and consequently the tensional balance of the fascia

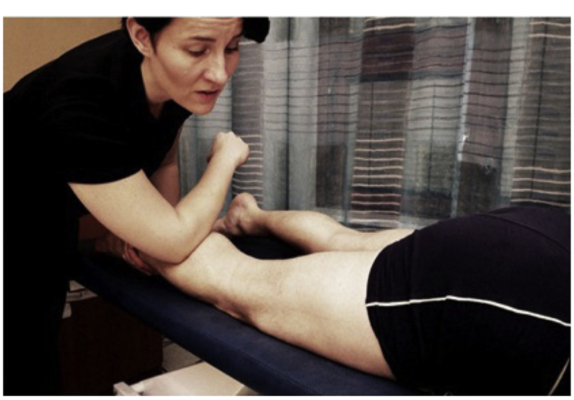

Figure 2 Treatment of the center of coordination RE-TA (retro-talus) according with the Fascial Manipulation© method.

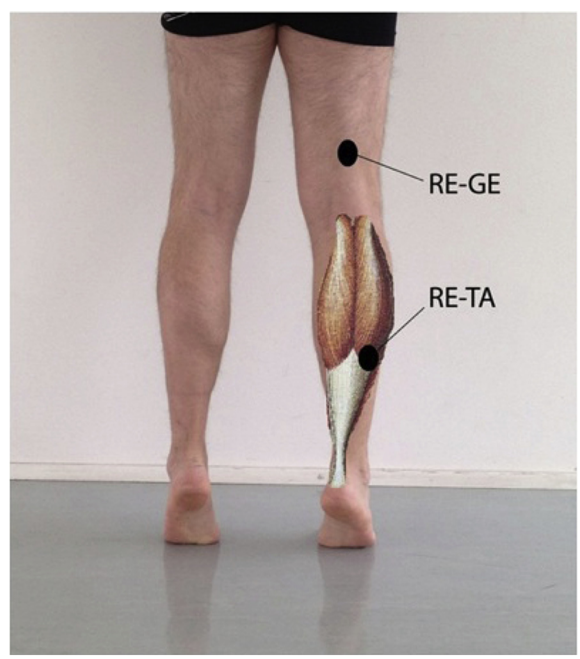

Figure 3 Anatomical localization of the center of coordination of RE-TA (RE = retro, meaning backward motion, and TA = talus, meaning ankle) and RE-GE (RE = retro, meaning backward motion, and GE = genu, meaning knee) according to the Fascial Manipulation© method. Location of the RE-TA is over the gastrocnemius muscle, in the lateral part of the muscle halfway up the calf, slightly towards the peroneus muscle. The RE-GE is located midway on the thigh, medial to the biceps femoris.

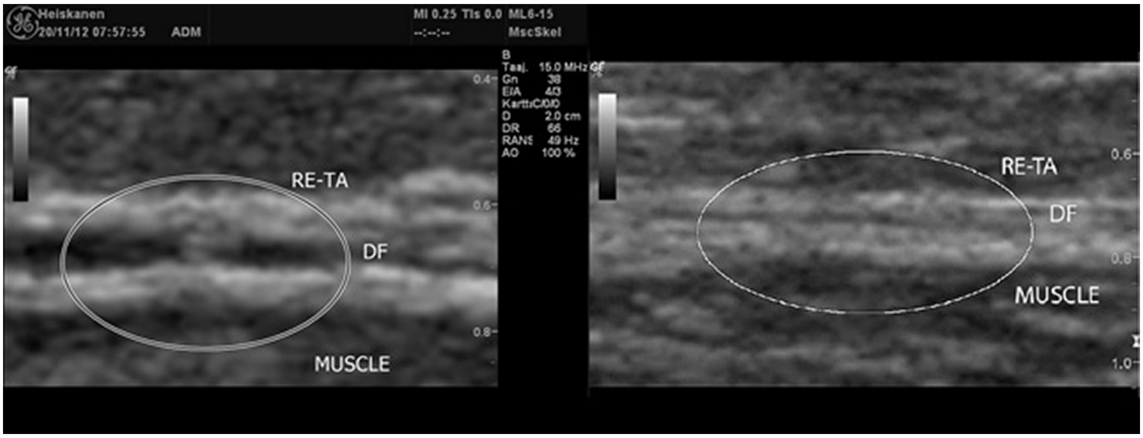

Figure 4 Ultrasound image of the center of coordination RE-TA. Left side image before Fascial Manipulation© and right side after the treatment. DF = deep fascia.

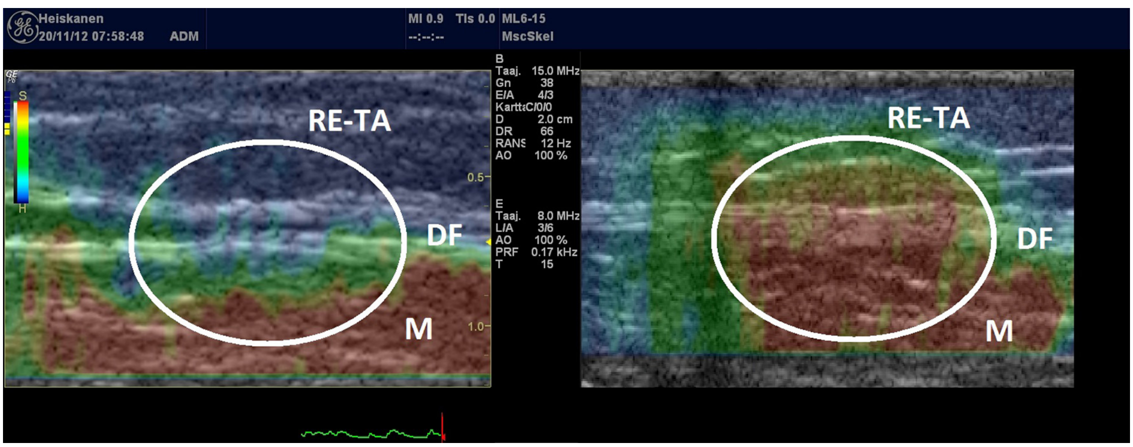

Figure 5 Elastography image of the center of coordination of RE-TA. Left side image before Fascial Manipulation© and right side after the treatment. The color blue indicates stiffer tissue, the color green softer and the color red the softest tissue. DF = deep fascial layers, M = muscle.

and the normal function of the underlying muscle (Stecco, 2004; Stecco and Stecco, 2009, Borgini et al., 2010).

For this study we selected two points, one in the calf area and the other in the posterior region of the thigh. These two points correspond to the centers of coordination of RE-TA (RE = retro, meaning backward motion, and TA = talus, meaning ankle) and RE-GE (RE = retro, meaning backward motion, and GE = genu, meaning knee) according with the Fascial Manipulation© method. Location of the RE-TA is over the gastrocnemius muscle, in the lateral part of the muscle halfway up the calf, slightly towards the peroneus muscle. The RE-GE is located midway on the thigh, medial to the biceps femoris (Fig. 3). The first point was very painful and densified on palpation, and its pressure caused referred pain into the heel. These elements are considered key elements for the Fascial Manipulation© method to decide if a point needs to be treated. The point in the middle of the thigh (RE-GE) was asymptomatic on palpation (no signs of radiation, pain or densification) and consequently was used as a reference point. These two centers of coordination were identified with a black marker.

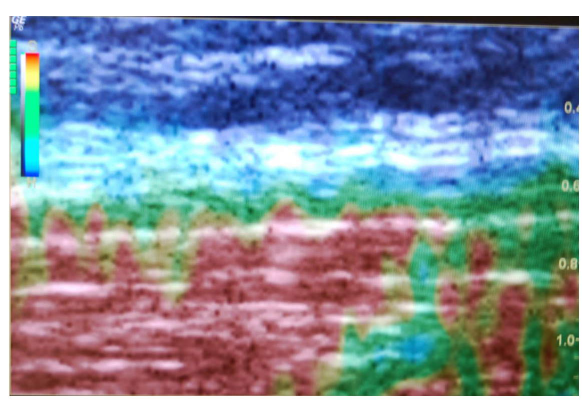

Figure 6 Comparison of the elastography image of the center of coordination RE-GE. The palpation of this center of coordination showed no signs of radiation, pain or densification, and elastography reveals that the fascial layers are soft (red color). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Ultrasound and elastography imaging was performed in the RE-TA area before and after Fascial Manipulation© and in the RE-GE point as a comparison. All images were taken from the same black marked spot. Patient was lying prone on the plinth, feet off the table so that free ankle movement was possible while palpating, imaging and treating. The whole procedure was conducted in the same posture. Movement, which was used to measure fascial gliding at the RE-TA point was active, maximal ankle dorsi- and plantarflexion. The treatment of the RE-TA area was carried on until relaxation was sensed by the both patient and the therapist. The person who did the ultrasound imaging was a medical doctor, who had practiced fascial imaging for more than six years. In measurement the ultrasound transducer was parallel to the muscle force direction and perpendicular to the examined area. Images were taking with the LOGIQ P6 ultrasound system with linear probe (transducer) 6–15 MHz (in this project 9–15 MHz) and elastography imaging. A Fascial Manipulation© trained physiotherapist carried out the marking, palpation and treatment.

Results

Before the Fascial Manipulation© treatment, ultrasound showed a clear hypoechoic area beneath the marked point in the calf area (center of coordination of RE-TA). The hypoechoic area was located in the deep fascia. After Fascial Manipulation©, it was smoother and the hypoechoic area seems to be thinner (Fig. 4). The elastography revealed the changes in fascial layers elasticity which was evaluated visually (this is reliable method for example in cardiology). By elastography, the densified area of the RE-TA appeared, before treatment, as a clear blue area

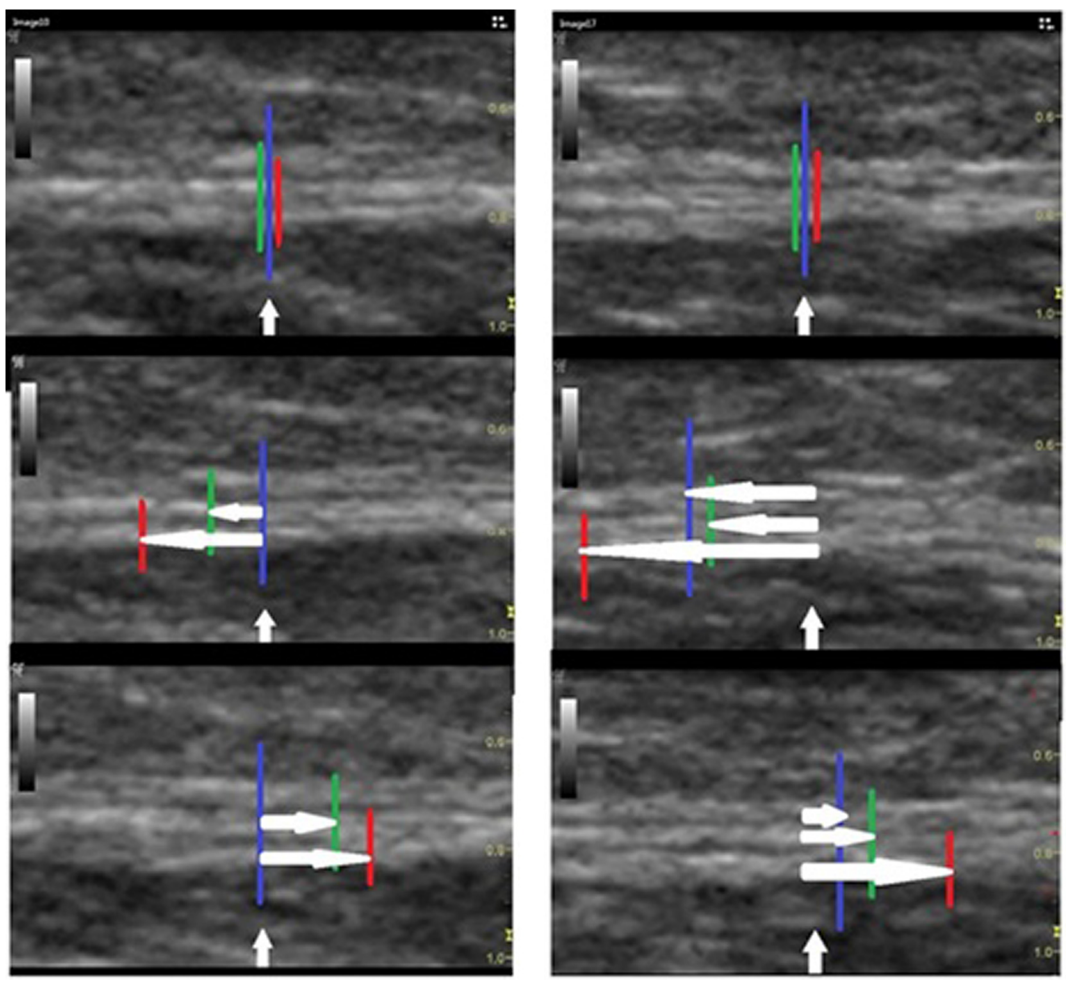

Figure 7 Relative movement of the fascial layers. The arrows and lines are markers of the level of fascial movement in the different layers. Vertical arrows point to the relative center point during the resting state. The blue line points to the superficial layer of the deep fascia, the green line to the middle layer, and the red line to the deepest layer. Finally, the white vertical arrow marks the relative center point of the resting state. In turn, the white horizontal arrows mark the movement of the each fascial layer. Before Fascial Manipulation©, no movement is visible in the superficial part of the deep fascia. However, the middle layer and the deepest layers moved slightly. After Fascial Manipulation©, all of the layers seem to glide more freely. The largest movement appears to occur in the deepest part of the deep fascia, although the superficial layer gained the most, movement compared to the starting point. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(stiff) surrounded by the green (softer) and red areas (soft). After treatment the blue area diminished and the fascial layers became more elastic as can be seen by the increment of green and red colors. Thickness of the deep fascia in the ultrasound image was 0.6–0.8 cm (Fig. 5). The fascial layers in the thigh (RE-GE), used as a comparison point, were soft (red color) at elastography (Fig. 6).

The ultrasound videoclips were analyzed to evaluate the gliding of the three fascial sublayers during muscle contraction in the area of the RE-TA. Before Fascial Manipulation©, no movement was visible in the superficial part of the deep fascia. However, the middle layer and the deepest layers moved slightly. After Fascial Manipulation© treatment, all of the layers seemed to glide more freely. The largest movement appeared to occur in the deepest part of the deep fascia, although the superficial layer gained the greatest degree of movement compared to the starting-point (Fig. 7).

Conclusion and discussion

According to these ultrasound and elastography images, the densification and movement dysfunction seems to be visible in the deep fascia. In particular, myofascial pain seems to be associated with reduction of gliding between fascial sublayers and in a changing in elasticity of the deep fascia. In this study palpation of these fascial gliding disturbances and densifications, appears to correlate with the ultrasound and elastography findings. With this experiment it is possible to observe that Fascial Manipulation© treatment increases fascial gliding and local viscoelasticity. This case study proposes that manual treatment causes mechanical effects and changes in the deep fascia.

The ultrasound and elastography imaging seem to be useful tools to help clinicians in the diagnosis of myofascial pain and in demonstration of the results of manual therapies. There are certain limitations in this study: ultrasonography, palpation and treatment are operator depending methods. In the field of elastography and ultrasound imaging these problems will be probably resolved by technological progress. For instance, Gennisson et al. (2013) describe new ultrasound technology that removes operator subjectivity by replacing hand-held pressure with an automated device. Also myotonometry (Myoton) has been used to determine musculoskeletal stiffness and to objectify the sensation of the clinicians.

In the future, it would be interesting to compare ultrasound imaging and patients' clinical symptoms, in particular the movement patterns and levels of pain. Elastographic imaging of the longevity of the changes after manual therapy represents another intriguing future research avenue. Improved palpation skills and comparison with ultrasound techniques, may offer greater information of the fascial system and its function *in vivo*.

Disclaimer form

Tuulia Luomala and Mika Pihlman are Fascial Manipulation© trained physiotherapists. They performed the treatment and the study.

Dr. Jouko Heiskanen performed the ultrasound and elastography studies.

Dr. Stecco Carla is the daughter of Stecco Luigi and a founder member of the Fascial Manipulation Association. She helps in writing the paper.

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